THOUGHT READING CAPACITY

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ABSTRACT

Electroencephalographic, Magnetoencephalographic, and functional Magnetic Resonance Imaging reports of specific concept recognition in humans on hearing words, viewing images or words, and prior to vocalization are examined. These reports are consistent with an extensive literature on word category differentiation by electrophysiology and blood flow, which is reviewed. EEG discrimination of emotional states, and deception literature is surveyed along with non-invasive brain computer interface reports. Non-contact and remote methods of brain wave assessment are also considered. The literature treated lends some substantiation to press accounts and case anecdotes that thought reading is possible, and has had covert development.

INTRODUCTION

The Bible attributes to God the capacity to know the thoughts of men. [1] Most scientists are unaware that thought reading by electroencephalogram (EEG) was reported as feasible in work begun over 30 years ago, [2] which more recently a number of groups confirm by Electroencephalography (EEG), Magnetoencephalograpy (MEG), and functional Magnetic Resonance Imaging (fMRI) technologies. This review focuses on literature relating to technologic thought reading, though also treated are the discrimination of more general cognitive states, brainwave capture methods, and reports of thought reading development, apparently covert to open literature.

METHODS OF SPECIFIC CONCEPT RECOGNITION

The Defense Advanced Research Projects Agency in 1972 contracted Pinneo & Hall for work that a 1975 US technical report

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[b] Since the copyright date this article is updated in the Specific Concept Recognition, as well as the Proximate and Remote Brain Wave Capture Methods sections.

entitled “Feasibility Study For Design of a Biocybernetic Communication System.” The study concludes “that it is feasible to use the human EEG coincident with overt and covert speech as inputs to a computer for such communication” (covert speech is defined as verbal thinking). Error: Reference source not found The 149 page report [c] states: “enough information has been obtained . . . to specify the optimum parameters to use for an EEG operating system, and to suggest future research towards that end.”

Pinneo & Hall utilized templates for EEG word recognition constructed by averaging EEG patterns evoked by 9 words in each subject for visually presented words, and primarily utilized 4 electrodes over brain language areas for prediction. People with high hemispheric lateralization had EEG patterns for some words that frequently classified 100% correctly, regardless of the number of repetitions with stability over time. Over all words, however, classification accuracy for these people was 85% for overt speech, and 72% for words repeated to oneself, but solely by mental means without vocalization. Across all subjects specific word EEG patterns were classified 35% correctly for overt speech, and 27% correctly for covertly spoken words, but more people were in the 70-100% classification range than in the 10-15% range.[d] Subjects with low hemispheric laterality, particularly stutterers had near chance EEG classification. EEG concept recognition was actually 10-15% higher for pictures rather than words. Phrases containing similarly articulated words or homonyms were better recognized than these words alone without context.

A US Office of Naval Research funded government study reports characteristically distinct topography of amplitude and decay coefficient for sub-waveforms at frequencies from 15-60 Hz for recalled or viewed digits from 0 to 9, and the words yes or no at electrodes over left hemisphere Brodman’s Area 39/40 and right hemisphere occipital electrode position O_2 in 3 individuals with some indication of similarities between subjects.[3] Background activity unrelated to digit or word stimulus was cancelled out, and the author indicates that the usually studied Event Related Potential (ERP) waveform is a summed composite of sub-waveforms. All other studies here discussed analyzed such a composite ERP.

Suppes et. al. have the most extensive recent publications supporting and reporting specific EEG thought recognition starting in 1997, a year before the above report.[4] [5] [6] [7] [8] This work largely compares recognition improvement methods with some emphasis on a relative invariance of EEG concept representations across individuals.

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[c] Pinneo’s report does not include all experiments reported to the Defense Advanced Research Projects Agency in the six annual reports over the 3 year contract.

[d] Over the experiments presented by the report, chance would be from 6.5 to 14% depending on the size of tested vocabulary.

The procedures generally utilized Fourier transforms of both templates for recognizing words, and test samples with an optimal EEG frequency window, or filter selected for each subject. EEG word templates constructed by averaging each subject's responses (50 trials) at single electrodes resulted in less EEG word recognition, Error: Reference source not found than recognition templates averaged across all subjects (700 trials) [e] for bipolar electrode difference. Error: Reference source not found The latter technique produced recognition rates over seven words of 100% for visual images and auditory words. Error: Reference source not found [f] However, for visually presented words, recognition templates generated by excluding from the average the subject tested was better--75% than averaging within a subject or over all subjects. The waveforms for each presentation modality were very similar, and when recognition templates averaged across subjects in the modalities of visual images or words were utilized for recognizing other modalities (visual images or words & by audition), recognition still was generally 60-75%. Such results were despite inclusion of three subjects with English as a second language, and obvious hemispheric laterality confounds important to Pinneo & Hall, [g] such as one left handed and another ambidextrous subject. These results indicate a relative invariance of EEG representations for different concepts between subjects and perception modality, when averaging out and filtering noise. Matching templates to words is determined by the least amplitude difference between template and test word waveforms, when sampled at 814 difference points as squared and summed (Pinneo & Hall Error: Reference source not found had 255 samples per word).

Also examined are brain wave patterns for sentences. Recognizing the first sentence word by the same words individually presented, and the same words in sentences when cut and pasted was successful at a 50% recognition rate (with 8.3% as chance). Error: Reference source not found However for differentiating whole sentences, over 90% recognition was obtained for 48 sentences, as visually presented one word at a time. Error: Reference source not found

Averaged unfiltered auditory responses are classified 100% correctly by the superposition of 3 sine waves chosen from the frequency domain maxima for each word.Error: Reference source not found The same procedure when averaged across subjects and presentation modalities (visual images, visual and auditory words) classifies 100% of the words (or images) by 5 frequencies per concept,

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[e] Suppes points out that this may have been due to increased averaging per se.
[f] Though apparently only single electrodes or pairs were utilized for prediction, the best recognition rates were not always from the same electrode or pair.
[g] Almost half of the Pinneo report is devoted to resolving such confounds.

while data fit decreased only 6% compared to the filtered templates. Syllable classification is less successful, with six correct classifications out of eight examples from superposition of nine frequencies.

Two subjects in Suppes et al. 1997 Error: Reference source not found had 64 channel EEG recordings from which scalp current density can be calculated by the surface Laplacian, which filters artifacts from muscle activity. Recognition rates could be improved by 9 % in one subject, and 4 % in the other. [9] Both subjects had coincident foci maximally predicting recognition on the head.

Yes/no decision discrimination of 86% by spatio-temporal cross correlation is reported. [10] This was achieved from 4 electrodes over bilateral frontal and occipital sites. Differential equation measures of synchronization rate and average polarity also had high recognition rates of 78% and 81% respectively.

Magnetoencephalographic (MEG) recognition of viewed words is reported above chance significantly by 27% for recognition and 44% for accuracy [11] by a speech recognition classifier. Suppes et al. Error: Reference source not found Error: Reference source not found also investigated MEG word recognition with lesser results than for

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[1] The Bible Job 42: 2, Psalms 139: 2, 94: 11, I Chronicles 28: 9, Isaiah 66: 18.

[2] Pinneo LR and Hall DJ. "Feasibility Study for Design of a Biocybernetic Communication System" Report #ADA017405 National Technical Information Service (NTIS), 1975. Prepared for the Advanced Research Projects Agency Order #2034, Program Code #2D20, Contractor: Stanford Research Institute Contract dates: 2/9/72-8/31/76, SRI Project LSU-1936. (US cost ~$50.) vailable at http://www.slavery.org.uk/Pinneo.doc

[3] Dickhaut RH. Neuroelectric activity and analysis in support of direct brainwave to computer interface development. National Technical Information Service report # ADA350432, 1998. Available at: http://www.slavery.org.uk/spectra.pdf & http://www.freedomfchs.com/mindreadingspectra.pdf

[4] Suppes P, Lu Z, and Han B. "Brain wave recognition of words" Proc Natl Acad Sci 94: 14965-69, 1997. Printable free online thru Pubmed or at http://www.pnas.org/cgi/content/full/94/26/14965

[5] Suppes P, Han B, and Lu Z. "Brain-wave recognition of sentences" Proc Natl Acad Sci 95: 15861-66, 1998. Printable free online thru Pubmed or at http://www.pnas.org/cgi/content/full/95/26/15861

[6] Suppes P, Han B, Epelboim J, and Lu Z. "Invariance of brain-wave representations of simple visual images and their names" Proc Natl Acad Sci 96: 14658-63, 1999. Printable free online thru Pubmed or at http://www.pnas.org/cgi/content/full/96/25/14658

[7] Suppes P, Han B, Epelboim J, and Lu ZL. "Invariance between subjects of brain wave representations of language" Proc Natl Acad Sci 96(22): 12953-8, 1999. Printable free online thru PubMed or at http://www.pnas.org/cgi/content/full/96/22/12953

[8] Suppes P and Han B. "Brain-wave representation of words by superposition of a few sine waves" Proc Natl Acad Sci 97: 8738-43, 2000. Printable free online thru Pubmed or at http://www.pnas.org/cgi/content/full/97/15/8738

[10] Kim M-J, Shin S-C, Song Y, and Ryu CS. "Yes/No Discrimination With Spatio-Temporal Characteristics of EEG" Proceedings of the 23rd International Conference of the IEEE Engineering in Medicine and Biology Society 2: 2009-12, 2001. Abstract at http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1020625

EEG, but there is reanalysis of some of this data by more advanced classifiers for words presented by audition, and viewed with instruction to silently say the word. [12] Best single trial correct classification for heard words in a subject is 60.7 % over 9 words by Independent Components Analysis combined with Linear Discriminant Classification, but averages across subjects are 40.6 % for auditory, and 30.9 % for viewed words (words presented ranged from 7-12, so chance levels ranged from 8.3-14.3 %). Error: Reference source not found

There is apparently a Russian report of specific EEG word recognition before 1981. [13] The work is only known from a science reporter, and specifically unavailable, but is mentioned to aid this report's discovery, and because of the claim that specific words contain category information, which is of possible significance for word category differentiation studies.

Patents for EEG thought recognition exist. Electroencephalographic (EEG) instant detection by syllables of "a content of category which the testee wishes to speak" quotes Kiyuna et. al. Patent # 5785653 "System and method for predicting internal condition of live body." [14] A stated use: "the present invention may be use (sic) to detect the internal condition of surveillance in criminal investigation" by EEG. NEC Corporation licensed this patent. Mardirossian Patent # 6011991 "Communication system and method including brain wave analysis and/or use of brain activity" includes remote EEG communication with armed forces or clandestine applications. [15] This patent proposes transponder capable skin implants, utilizes artificial intelligence, and is licensed by Technology Patents, LLC.

A classifier based on computational linguistics correctly identifies the functional Magnetic Resonance Imaging (fMRI) pattern for 77 % of 60 nouns as averaged over 9 subjects, as well as correct prediction of the fMRI pattern for 72 % of 1000 frequent words. [16] Previous fMRI reports confirm similar capabilities for viewing pictures of objects with lesser classification methods. Comparing the distributed brain activity observed by fMRI for viewing faces, houses,

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[13] Selden G. "Machines That Read Minds" Sci Digest Oct 89: 60-6, 1981.

[14] Kiyuna T, Tanigawa T, and Yamazaki T. Patent #5785653 "System and method for predicting internal condition of live body" USPTO granted 7/28/98.

[15] Mardirossian A. Patent #6011991 "Communication system and method including brain wave analysis and/or use of brain activity" USPTO granted 1/4/00.

[9] de Barros JA, Carvalhaes CG, de Mendonca JPRF, and Suppes P. "Recognition of Words from the EEG Laplacian" Brazilian Journal of Biomedical Engineering 21(2-3): 143-50, 2005. At http://www.ecologia.ufjf.br/admin/upload/File/Barros%20et%20al.,%202006.pdf

[12] Guimares MP, Wong DK, Uy ET, Grosenick L, and Suppes P. "Single-Trial Classification of MEG Recordings" IEEE Trans Biomedical Engineering 54(3): 436-43, 2007.

cats, chairs, bottles, shoes, and scissors were 90-100% correct in all two category comparisons (with 50% as chance).[17] A different group confirms this analysis.[18] Even though all these objects are described as categories because different exemplars and views were presented, discrimination of these objects generally requires an adjective, so that the distinctions qualify as specific concepts. One report examined just 20 seconds of fMRI data rather than one half of an fMRI session in previous studies, and utilized different exemplars of an object category for training classifiers from those utilized during classification. A support vector classifier provided the best results with 59-97% accuracy among ‘categories’ of baskets, birds, butterflies, chairs, teapots, cows, horses, tropical fish, garden gnomes, and African masks (with 10% as chance).[19] “Brain reading” are descriptive terms titling this report. Another study reports 78 % average correct classification (range 59-94 %) for viewing across all line drawing exemplars for a drill, hammer, screwdriver, pliers, saw, apartment, house, castle, igloo, or hut with even better discrimination when considered as categories of tools and dwellings.[20] A quantitative fMRI receptive field model for the visual cortex could provide 92 and 72 % correct identification for 120 natural images novel to the viewing experience of each participant.[21] Visual cortex response to 440 multi-grey scale checkerboard-like patterns is reported to train local decoders to reconstruct viewed images that are correctly identified among millions of candidate images, and that effectively reads out perceptual state.[22] Though not here considered specific concepts, review of considerable ability to decode viewed line orientations or grids is available[23] that is expected related to fMRI and electrophysiological discrimination of viewed objects with one review considering such capacities as mind reading.[24] Particularly remarkable of such studies is above chance discrimination of imagined specific patterns in some subjects considering the lesser brain activity, and classifier model[25] compared to [Error: Reference source not found].

Numerous fMRI studies show similarly activated brain regions for viewing images or words, and hearing words. Viewing pictures of objects or the word naming them activates similar distributed brain systems for storing semantic knowledge,[26] [27] [28] and auditory presentation also shares the same[29] or a similar[30] system with that of viewing these words. These studies give anatomical basis for the high cross modality recognition rates of concepts observed by Suppes et al. Error: Reference source not found Error: Reference source not found

PHYSIOLOGIC DISCRIMINATION OF WORD CATEGORIES

Broca and Wernicke originally defined anatomy pertinent to aphasia resulting from brain injury.[31] More recently described are

brain lesion patients who have very selective agnosias, which is an inability to name or recognize specific object classes. [32] [33] [34] Many word category differentiation reports reviewed below were initiated to explain and substantiate such deficits. This literature is consistent with specific word recognition, because word responses are averaged by category, and distinguished with only statistical inspection without specific comparison to templates or by classifiers as is required for thought recognition. Brain cell assembly activation provides a theoretical framework for both specific concept recognition, and word category discrimination. [35]

Electroencephalographic and Magnetoencephalographic Word Category Discrimination

Evoked EEG responses discriminate nouns and verbs. Nouns elicit more theta power than verbs, but verbs have greater theta coherence decrease, particularly in frontal versus posterior sites. [36] Noun waveforms generally are more negative than verb responses at post-stimulus intervals of both 200-350 and 350-450 milliseconds (msec.). [37] [38] [39] [40] Ambiguous noun/verbs are more negative than unambiguous nouns or verbs in the early latency interval, and when context indicates noun meaning versus verb use, are more negative over both these latency windows. Error: Reference source not found Anterior-posterior electrode activity also differs for ambiguous versus unambiguous nouns and verbs. Error: Reference source not found [41]

Action verb waveforms differ in amplitude, Error: Reference source not found and central versus posterior distribution compared to visual nouns, [42] with particular 30 Hz increase over the motor cortex for action verbs, and over the visual cortex for visual nouns. [43] [44] Face, arm, or leg action verbs differ in amplitude by time interval, and activity increases over the specific corresponding motor strip locus as well as by frontal electrode. [45] [46] Low resolution electromagnetic tomography finds irregular verb activity more in the left superior and middle temporal gyri, while regular verbs are more active in the right medial frontal gyrus at 288-321 msec. [47] Irregular

[36] Khader P and Rosler F. “EEG power and coherence analysis of visually presented nouns and verbs reveals left frontal processing differences” Neurosci Lett 354: 111-14, 2004.
[37] Preissl H, Pulvermuller F, Lutzenberger W, and Birbaumer N. “Evoked potentials distinguish between nouns and verbs” Neurosci Lett 197: 81-3, 1995.
[38] Kellenbach ML, Wijers AA, Hovius M, Mulder J, and Mulder G. “Neural Differentiation of Lexico-Syntactic Categories or Semantic Features? Event-Related Potential Evidence for Both” J Cog Neurosci 14(4): 561-77, 2002.
[39] Khader P, Scherag A, Streb J, and Rosler F. “Differences between noun and verb processing in minimal phrase context: a semantic priming study using event-related brain potentials” Cogn Brain Res 17: 293-313, 2003.
[40] Federmeier KD, Segal JB, Lombrozo T, and Kutas M. “Brain responses to nouns, verbs and class-ambiguous words in context” Brain 123(12): 2552-66, 2000.

verbs respond more in the left ventral occipito-temporal cortex than regular verbs at ~340 msec. by MEG, which localizes perpendicular sources undetectable by EEG. [48] Regular verb activity modulates more the left inferior prefrontal region including Broca's area at ~470 msec with MEG, but irregular verbs have more right dorsolateral prefrontal cortex activity at ~570 msec. Priming evoked patterns occur for regular but not irregular verbs, [49] [50] while incorrect irregular noun plural [51] and verb participle [52] [53] waveforms differ from that of incorrect regular forms.

Abstract word waveforms onset more positively about 300 msec., persist longer at lateral frontal sites, and distribute more to both hemispheres compared to concrete words.Error: Reference source not found [54] [55] β-1 frequency coherence during memorization of concrete nouns indicates left hemisphere electrode T5 as the main brain processing node. [56] Left hemisphere electrode T3 is similarly important for abstract nouns, which have more frontal area contribution, and massive right posterior hemisphere coupling. Error: Reference source not found Abstract versus concrete memorization distinctly changes other frequency bands, [57] [58] and theta synchronization predicts efficient encoding. [59]

Content words yield a more negative peak at 350-400 msec. than functional grammar words, with a subsequent occipital positivity that function words lack, and more electrode and hemisphere differences from 400-700 msec. [60] [61] In sentences, the late component of function words resembles preparatory slow waves that apparently subserve their introductory and conjunctive grammatical function. [62] Other studies show content versus function word differences at additional intervals and more bi-hemispheric effects,[63] with right visual field advantage for function words. [64] MEG distinguishes functional grammar words, or content words such as multimodal nouns, visual nouns, or action verbs, each by response strength and laterality at intervals of both ~100 and greater than 150 msec. [65]

Proper name amplitudes peak more just after 100 msec. negatively, and just after 200 msec. positively than common nouns, while one's own name accentuates these peaks relative to other proper names with further positive and negative components. [66] Proper names, animals, verbs, and numerals show electrode site differences: proper name temporal negativity extends to inferior electrodes bilaterally; verbs and animal names are less negative and similar, but verbs have left frontal inferior positivity; while numerals

[60] Neville HJ, Mills D, and Lawson DS. "Fractionating Language: Different Neural Subsystems with Different Sensitive Periods" Cerebral Cortex 2: 244-58, 1992.
[61] Munte TF, Wieringa BM, Weyerts H, Szentkuti A, Matzke M, and Johannes S. "Differences in brain potentials to open and closed class words: class and frequency effects" Neuropsychologia 39: 91-102, 2001.
[62] Van Petten C and Kutas M. "Influences of semantic and syntactic contex on open- and closed-class words" Mem Cogn 19: 95-112, 1991.

have less waveform negativity, and bilateral parietal positivity. [67] Non-animal objects are more negative in both the 150-250 and 350-500 msec. intervals than animals, while animals are more positive in the 250-350 msec. interval. [68] [69] Animals are more positive in approximately the same latter interval than vegetables/fruits, while vegetables/fruits are more negative in about the earlier interval (150-250 msec.), and have stronger frontal region current sources than animals. [70] Animals in natural scenes evoke different waveforms than just natural scene or building pictures. [71] Responses to words for living things are less negative over the right occipital-temporal region than artifactual objects, while pictorial presentations of the same items further differ and have hemisphere effects noted as unreported. [72] EEG waveforms for specific meanings could be as discretely categorized as indicated by the reported but unspecified Russian work, which claims that “the waves for such concepts as “chair”, “desk”, and “table” are all overlapped by another wave that corresponds” to the concept of furniture. Error: Reference source not found

Affective word meanings such as good-bad, strong-weak, or active-passive are discriminated [73] by both category and meaning polarity according to response latency, amplitude, and scalp distribution at intervals of 80-265 and 565-975 msec. [74] Positive words have amplitude increases peaking at 230 msec. compared to negative words, and relative to neutral words increase a subsequent peak amplitude as well as a slow wave component. [75] Emotional words also show less amplitude decrease on repetition than neutral words. [76]

Some of these word category differentiation reports are consistent with both the specific recognition reports, and/or the discrimination of non-verbal cognition. Based on EEG/MEG responses, words are readily distinguished from non-words, [77] [78] [79] pictures, [80] and as to length. [81] Even commas have a characteristic waveform similar to the speech phrase closure evoked pattern called closure positive shift. [82] Color selection modulates the EEG. [83] EEG discriminates the judgment of gender for both faces and hands. [84]

Positron Emission Tomography (PET) and Functional Magnetic Resonance Imaging (fMRI) Word Category Discrimination

Positron Emission Tomography (PET) and Functional Magnetic Resonance Imaging (fMRI) localize brain blood flow, with ability to distinguish perceptual categories. Some studies locate recognition of places [85] [86] and faces [87] within certain brain areas, however, expertise can recruit the face recognition area, [88] and other studies show these areas only responding maximally for specific stimuli. [89] Word category activity is both distributed and overlapping Error: Reference source

not found [90] in a somewhat lumpy manner. [91] Though regions of word category maximal difference are indicated below, brain comprehension is not solely dependent on these areas. Discrete category responsive emergence may have some resemblance to category segregation in the feature processing of artificial neural networks that self organize without programming. [92]

Meta-analysis of 14 studies locating activity for face, natural, and manufactured object recognition shows ventral temporal cortex difference. Face recognition activates more inferior ventral temporal portions including the fusiform gyrus of which manufactured objects activate more medial aspects than face or natural objects, yet natural objects distribute more widely in this region. [93] Eighty eight percent of face studies converged for mid fusiform gyrus activity, while natural and manufactured objects converged no more than 50% for any discrete area. Manufactured object activity locates to the middle temporal cortex from natural objects, which locate more in the superior temporal cortex. Face and natural object activity is more bilateral, and in the left inferior frontal cortex, while particularly tools activate the premotor area. These studies also feature activity in the inferior occipital/posterior fusiform as well as the medial occipital structures of lingual gyrus, calcarine sulcus, and cuneus.

There is some agreement that verbs have greater activity in temporal, parietal, and premotor/prefrontal regions than nouns, while nouns have little [94] or no [95] greater activated areas than verbs, yet no noun/verb difference is also reported. [96] German regular noun and verb fMRI responses compared to irregular words differ significantly in the right precentral gyrus, the left prefrontal cortex, bilateral posterior temporal lobes, and bilateral complexes including superior parietal lobules, supramarginal gyri, and angular gyri. [97] Regular words are left hemisphere lateralized, while irregular words have somewhat greater distribution to the right hemisphere, and a greater activation over all cortical areas. Irregular verbs activate more total cortex than regular verbs, but lack motor strip, insular, and most occipital cortex activity present for regular verbs. [98] Though both forms activate the inferior parietal lobule, irregular verbs activate more posterior and superior portions than regular verbs.

Depending on control task correction, naming actions activates the left inferior parietal lobule, which is lacking for locative prepositions, which activate the left supramarginal gyrus selectively from actions. [99] Furthermore, naming abstract shape location compared to locating concrete items increases right supramarginal gyrus activity, Error: Reference source not found which specifically also activates on long-term memory for spatial relations [100] and in American sign language prepositions. [101] The supramarginal gyrus is encompassed by the temporal-parietal-occipital junction active for location judgments, and is separate from temporal activity for judging

color. [102] Action word generation activity is just anterior to the motion perception area, while color word generation activity is just anterior to the color perception area. [103] Naming object color activates distinct brain regions from naming the object, with color knowledge retrieval activity being slightly removed from that of naming colors. [104] Irrespective of language and visual or auditory modality, the naming of body parts activates the left intraparietal sulcus, precentral sulcus, and medial frontal gyrus, while naming numbers activates the right post central sulcus as joined to the intraparietal sulcus. Error: Reference source not found

Concrete words are discriminated from abstract words in both noun or verb forms, Error: Reference source not found with more right hemisphere activity for abstract words than concrete words. [105] [106] [107] Abstract/concrete contrasts feature both right or left temporal areas, while the reverse concrete/abstract comparison features frontal activity. [108] [109] [110] [111] [112] Besides distinction from abstract nouns, the concrete categories of animals contrasted to implements respond selectively in the posterior-lateral temporal, and frontal cortex areas across studies. Error: Reference source not found Error: Reference source not found Limbic activity, particularly the cingulate, distinguishes emotional words from both abstract and concrete words. Error: Reference source not found

Naming pictures of animals, tools, and famous people are discriminated [113] by increased regional blood flow in the left inferior frontal gyrus for animals, premotor area for tools, and left middle frontal gyrus for people. [114] Faces activate the right lingual and bilateral fusiform gyri, while the left lateral anterior middle temporal gyrus response differs to famous faces, famous proper names, and common names. [115] Particularly the left anterior temporal cortex responds to names, faces, and buildings when famous relative to non-famous stimuli. Error: Reference source not found [116] Viewing photographs of faces, buildings, and chairs evokes activity distributed across several cortical areas, which are each locally different in the visual, ventral temporal Error: Reference source not found and occipital cortices. [117] Photograph perception of these same categories has more hemispheric lateralization and activation than non-perceptual imagery, [118] while short term memory face imagery activity is stronger than that of long term memory. [119]

More advanced fMRI techniques discriminate further word or object classes. In a high resolution fMRI limited brain cross section study; the activity differs for animals, furniture, fruit, or tools in discrete sites of the left lateral frontal and 3 separate medial temporal cortex loci respectively. [120] The application of artificial intelligence to fMRI patterns distinguishes between 12 noun categories (fish, four legged animals, trees, flowers, fruits, vegetables, family members, occupations, tools, kitchen items, dwellings, and building parts). [121]

Finally are the reports of discriminating the viewing different 'categories' Error: Reference source not found Error: Reference source not found Error: Reference source not found so discrete as to require an adjective for distinction, and those acknowledging specific concept recognition Error: Reference source not found Error: Reference source not found as well as prediction of photograph perception, Error: Reference source not found previously discussed.

Some cognitive functions are related to or partly dependent on language. Letters activate the left insula more than objects and exclusively activate the left inferior parietal cortex. [122] Letters also activate an area in the left ventral visual cortex more than digits in most subjects. [123] [124] Brain activations of mathematical thinking are partly dependent on language. [125] Subtraction activates bilaterally the anterior intraparietal sulcus and a phoneme area in the intraparietal sulcus mesial to the angular gyrus, selectively from simple motor tasks. [126] Number comparison activates right hemisphere intraparietal and prefrontal areas, while multiplication localizes more to the left hemisphere. [127]

ELECTROENCEPHALOGRAPHIC DISCRIMINATION OF OTHER COGNITIVE STATES

Other literature indicates EEG differentiation of completely non-verbal cognition. Greater left prefrontal activity predicts positive affect, while greater right prefrontal activity predicts negative disposition in psychological testing. [128] However, the stability of hemispheric activation is important for such a trait characteristic, [129] and more transient mood states have exactly the opposite arousal symmetry. [130] Decreased left prefrontal activity is also found in depression, [131] [132] and the anxiety situations of social phobics. [133] Patented is more specific attitude, mood, and emotion differentiation, by plotting at least two and as many as five EEG frequencies, with reference to Air Force research. [134] EEG patterns discriminate relative misanthropy and philanthropy in facial preferences, and favorable or negative responses to faces, [135] while waveform topography identifies sad face perception. [136] Another EEG emotion indicator is the stimulus-preceding negativity (SPN). Although slight SPNs can precede instruction cues, this wave is most pronounced while awaiting performance assessment and reward or aversive feedback. [137] [138] [139] [140]

A number of groups have developed procedures to detect deception based on the P300 (positive @ 300 millisec.) event related potential (ERP) from EEG. [141] [142] [143] [144] [145] [146] Brain Fingerprinting is a commercial system, [147] which includes additional frequency analysis, particularly a late negative ERP potential, and cites 100% accuracy over five separate studies. [148] [149] [150] [151] [152] Though most EEG deception

detection concerns situation specific knowledge, a late positive potential approximate to the P300, is reported to vary as a function of real attitude rather than attitude report. [153]

BRAIN COMPUTER INTERFACES

EEG cortical potentials are detected for both actual movement, [154] and movement readiness potentials (bereitschaftspotential). [155] [156] EEG sufficiently differentiates just the imagination of movement to operate switches, [157] move a cursor in one [158] or two dimensions, [159] control prosthesis grasp, [160] and guide wheel chairs left or right [161] for prompted responses. EEG detects such potentials to play Pac Man, [162] and imagining the spinning of cubes, or arm raising in appropriate direction guides robots through simulated rooms, [163] [164] [165] both achieved without response prompting. Unprompted slow cortical potentials also can turn on computer programs. [166] Signals from implanted brain electrodes in monkeys achieve even more complex grasping and reaching robot arm control without body arm movement. [167] Some ability to recognize evoked responses to numbers [168] and tones [169] in real time by a commercial system called BrainScope has limited report.

PROXIMATE AND REMOTE BRAIN WAVE CAPTURE METHODS

EEG is typically recorded by contact electrodes with conductive paste, while MEG detectors are in an array slightly removed from the head. Remote detection of brain rhythms by electrical impedance sensors is described. [170] Though non-contact is the only remote descriptor for EEG, this same detector design is applied to monitoring electrocardiogram with wrist sensor location. [171] Passive brain wave fields extend as far as 12 feet from man as detected by a cryogenic antenna. [172] This device is entirely adaptable to clandestine applications, and pointed comments are made on the disappearance of physiological remote sensing literature since the 1970’s for animals and humans, while all other categories of remote sensing research greatly expanded. [173]

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[170] Harland CJ, Clark TD, and Prance RJ. “Remote detection of human electroencephalograms using ultrahigh input impedance electric potential sensors” Appl Physics Lett 81(17): 3284-6, 2002.

[171] Harland CJ, Clark TD, and Prance RJ. “High resolution ambulatory electrocardiographic monitoring using wrist mounted electric potential sensors” Meas Sci and Technol 14: 923-8, 2003. Abstract at http://www.iop.org/EJ/abstract/0957-0233/14/7/305

[172] Taff BE and Stoller KP. Patent #4940058 “Cryogenic remote sensing physiograph” USPTO granted 7/10/90.

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In 1976, the Malech Patent # 3951134 "Apparatus and method for remotely monitoring and altering brain waves" was granted.[174] Example of operation is at 100 and 210 MHz, which are frequencies penetrating obstruction.[175] "The individual components of the system for monitoring and controlling brain wave activity may be of conventional type commonly employed in radar"; and "The system permits medical diagnosis of patients, inaccessible to physicians, from remote stations" are quotes indicating remote capacity. License is to Dorne & Margolin Inc., but now protection is expired with public domain. The Malech patent utilizes interference of 210 and 100 MHz frequencies resulting in a 110 MHz return signal, from which EEG waveform is demodulated.

A capability for 'remote EEG' is predicted by electromagnetic scattering theory using ultrashort pulses,[176] which is different from the unpulsed Malech patent. Sampling rate for EEG specific concept recognition is only 1000 Hz (10^3/sec.), Error: Reference source not found compared to common radio frequency technology available at picosecond pulse widths allowing a considerably higher sampling rate. Current review of microscopic electric field imaging describes phase, amplitude, and polarization changes of reflected waveform that would be expected to propagate at distance, and be detectable.[177]

In addition to the radio frequency ultrashort pulse and interference methods above that are compatible with target tracking radars, the capacity to detect remote electric field changes is evident in present Radio Frequency Identification Device (RFID) technology. Passive and semi-passive RFID tags encode information by electrically induced impedance changes that modulate the power of the backscattered 'echo' according to the equation:[178]

$$P_S = I^2 \cdot R_r$$

Where: P_S = Power reflected by an antenna.
I = Current.
R_r = Radiation resistance of antenna (without current).

Semi-passive RFID tags have a battery supplying current that modulates the backscatter mechanism with present read ranges as far as 30.5 meters under commercial reader power regulations,[179] but military capabilities considered include targeting of RFID tags by missiles.[180] Though the above equation stipulates antenna properties, the human body is regarded as an antenna by several treatments.[181] [182] [183] [184] Comparing the occurrence of human EEG current as on the order of microamps[185] to descriptions of RFID practical operation from 2.5-25 microamps, Error: Reference source not found and at the nanoamp level[186] provides support for design approaches to gaining

radar encephalographic information by this mechanism. The electrically modulated scatterer literature dates back to 1955. [187]

A dissertation exists on microwave detection of neural activity in cockroaches [188] along with related work apparently presented at a symposium, [189] and a portable diagnostic microwave patent for a detector of neural activity that describes animal studies. [190] Though the dissertation suggests electro-mechanical impedance changes, the patent indicates that there is more direct electrical modulation of microwave backscatter, and operation at continuous wave. Though not developed for remote application, this system has some correspondence to RFID electric field modulated backscatter methods. Review of the feasibility for imaging brain neuronal electrical activity by methods potentially capable of rather stringent resolution requirements considers other approaches to bioelectric field imaging. [191]

THOUGHT READING COVERT DEVELOPMENT EVIDENCE

The research arm of agencies mandated to covertly acquire information would certainly develop to operational capability any thought reading potential, which was reported feasible 30 years ago to the Department of Advanced Research Projects Agency (DARPA). Reports that such development has progressed are multiple, and two are confirmed by details of the 1975 DARPA EEG specific word recognition report, which itself is evidence of development covert to open databases. Error: Reference source not found An International Committee of the Red Cross Symposium synopsis states EEG computer mind reading development by Lawrence Pinneo in 1974 at Stanford. [192] A letter by the Department of Defense Assistant General Counsel for Manpower, Health, and Public Affairs, Robert L. Gilliat affirmed brain wave reading by the Advanced Research Projects Agency in 1976, [193] the same year as the Malech remote EEG patent grant. Neglect of developing such a capacity by security institutions in the 22 years between the Pinneo report and relatively recent confirmations is not credible. The further Dickhaut, 1998 Government report Error: Reference source not found appears more advanced than the journal literature, while the National Technical Information Service's database is only clumsily searchable with availability limited by charge of commercial copyright rates for public information.

Dr. John Norseen of Lockheed Martin Aeronautics is quoted in news articles that thought reading is possible and has had development.[194] [195] At least knowledge of Dickhaut, 1998 Error: Reference source not found is evidenced in reference by a Norseen presentation, [196] but he predicted by 2005 the deployment of thought reading detectors for profiling terrorists at airports. Error: Reference source not found A further acknowledgement of developing a device

to read terrorists' minds at airports was made in a NASA presentation to Northwest Airlines security specialists. [197] Statements in all news articles indicate remoteness of brain wave detection, though somewhat proximate.

"Thought reading or synthetic telepathy" communications technology procurement is considered in a 1993 Jane's[h] Special Operations Forces (SOF) article: "One day, SOF commandos may be capable of communicating through thought processes." [198] Descriptive terms are "mental weaponry and psychic warfare." Although contemplated in future context, implied is availability of a technology

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with limited mobility, since troop deployment anticipation must assume prior development. Victim complaints that mind reading is part of an assault upon them are very similar to such a capacity. Other complaints by these victims, such as technologically transmitted voice assault are upheld by considerable documentation that individually isolated voice transmission is feasible, even at a distance and within structures, Error: Reference source not found and a presumptive diagnosis of such complaints is largely consistent with microwave exposure [199]--a basis for both internal voice and EEG capture technologies.

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DISCUSSION

There is considerable confirmation of an ability to recognize specific concepts by brain activity across subjects at some level of accuracy. Identifying visual images viewed by a subject solely by measures of mental activity is replicated across seven groups by either EEG or fMRI. Five groups report success in visually viewed word identification by brain activity in these methods. Isolated groups report EEG word recognition by auditory perception, prior to

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vocalization, or as independently recalled. Although many studies examine lesser sets of concepts, when added together the collective differentiation of these smaller sets approaches 100, and recent reports Error: Reference source not found Error: Reference source not found differentiate even larger comparison numbers with a report of effective visual cortex image decoding. Error: Reference source not found In all, ten separate groups report some level of specific concept recognition by EEG, MEG, or fMRI. Word category distinctions are expected from these specific differences. EEG, MEG, PET, or fMRI techniques discriminate some 42 word class or dimension distinctions,

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many of which would survive separate direct comparison just by reported results.

Considerable capacity to specifically detect and differentiate other mental states is evident from literature reports by EEG. The fact that EEG signals are detected on a voluntary unprompted basis for turning on computer programs, Error: Reference source not found playing Pac Man, Error: Reference source not found and robot guidance Error: Reference source not found Error: Reference source not found Error: Reference source not found suggests the feasibility of a similar capacity for specific EEG concept recognition. Although most concept recognition work is related to stimulus prompted responses, unprompted detection of numbers apparently as a class, has limited report. Error: Reference source not found

The finding that words can be classified by superposition of sine waves Error: Reference source not found or by frequency sub-waveform topography Error: Reference source not found suggests an obvious interpretation, when considering word category blood flow

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activations of cell assemblies. Error: Reference source not found The frequencies resulting from neuron firing rates in the distributed, yet somewhat discrete regions, when interference phase summed and subtracted by arrival from different locations results in word representation in the brain's language. Such results and the fact that the best recognition rates for words are obtained by the difference between an electrode pair Error: Reference source not found Error: Reference source not foundsupports the concept that a resultant waveform would provide similar information.

Remote electric field determination of such a resultant waveform for decoding the encephalogram does have covert development indication by news reports. The potential for thought reading and such a remote capacity is cautioned by French

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government scientific panel. [200] At various levels of remoteness numerous methods or potentially exploitable mechanisms for detecting brainwave activity are described in open literature.

Complete rejection of reports of a remote mind reading capability is just as presumptuous, in the face of complaints, as has been the dismissal of remote voice transmission capacity. Error: Reference source not found News reports of covert thought reading development have some confirmation in the Pinneo 1975 study Error: Reference source not found and Dickhaut, 1998 Error: Reference source not found with independent news assertions of somewhat remote thought reading development "against terrorists" affirming each other. Special operations officials consider procurement of a similar remote capacity to that of which many victims complain. Though victims will regard their experience to affirm such a thought reading capability, professional prejudice classifies such complaints as within Schneiderian symptoms defining psychiatric condition. The certain fact is that these claims have had no adequate investigation, and the available evidence questions the routinely egregious denial of civil rights to such individuals. Complaints involving mind reading must at least receive rational investigation rather than ignorant

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professional dismissal convenient to practice with lucrative livelihood benefit.

It is known that government elements have done work in thought reading development. The logic that in the 30 years since the Pinneo work started, this capacity is operationally applied is too sound to dismiss victim corroboration and other evidence. Funding for projects by the defense and security agencies is considerably greater than for open science, and thought reading would unquestionably be a priority area. Except for the evidence for misuse as conjuncted with another radio frequency communications technology, [201] Error: Reference source not found [202] and numerous obvious indications of such a capacity freely available, this author would prefer the information remain classified. Particularly disturbing is the existence of remote electric field determination methods in the public domain. Educated democracies should not be complacent at any prospect of mind reading, given the potential for privacy loss, civil rights violation, and political control.

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